

Award-Wining System Assays Radioactive Waste with Radiation

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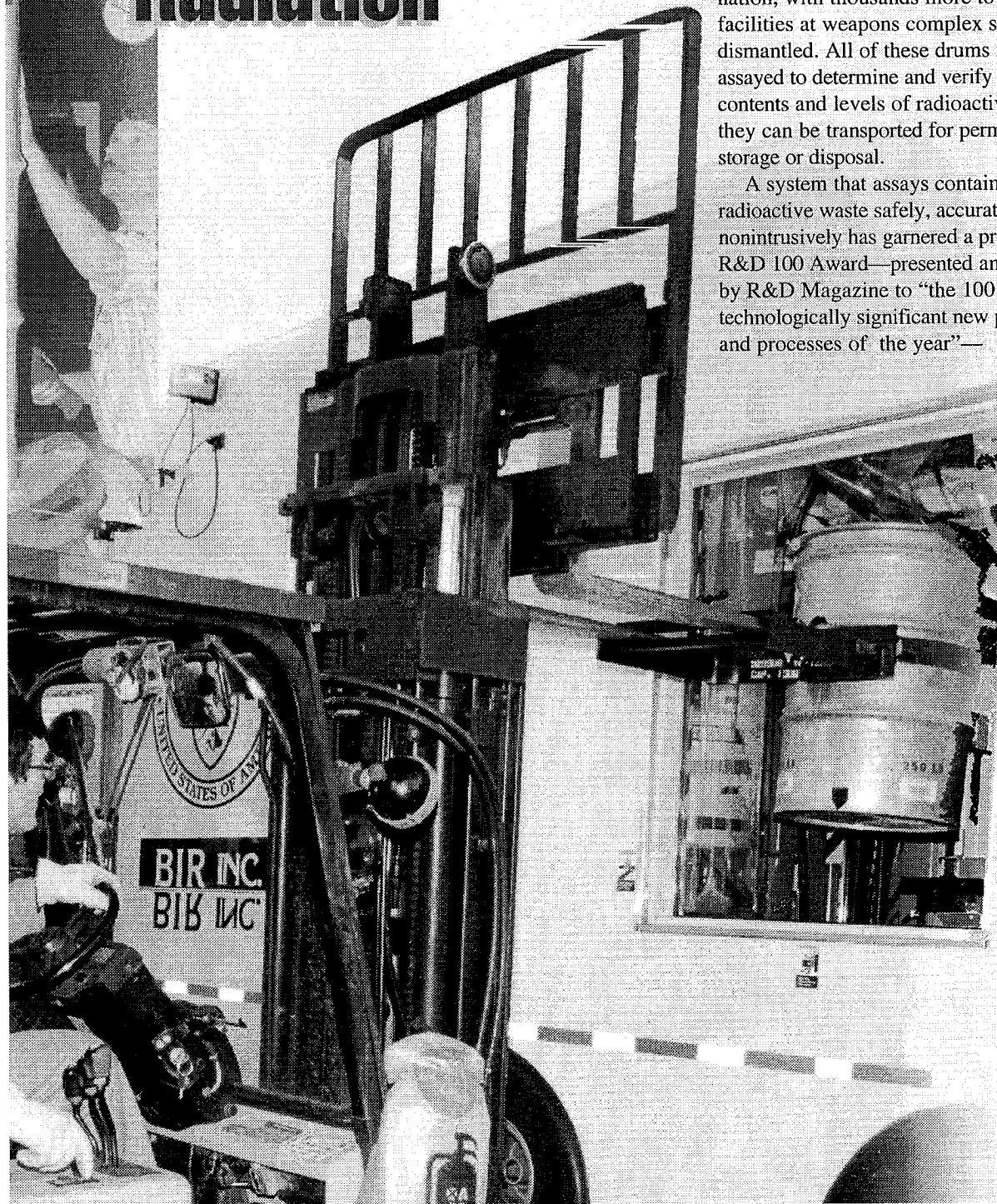
MORE than half a million drums of radioactive waste are stored at 30 Department of Energy sites across the nation, with thousands more to come as facilities at weapons complex sites are dismantled. All of these drums must be assayed to determine and verify their contents and levels of radioactivity so they can be transported for permanent storage or disposal.

A system that assays containers of radioactive waste safely, accurately, and nonintrusively has garnered a prestigious R&D 100 Award—presented annually by R&D Magazine to “the 100 most technologically significant new products and processes of the year”—

Bio-Energy Research, Inc. of Lincolnshire, Illinois, is collaborating with Livermore researchers in nondestructive evaluation (NDE). Here, BIR's trailer is the site of an experiment using active and passive computed tomography to identify and quantify materials inside nuclear waste drums.

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for Lawrence Livermore National Laboratory and its commercial partner, Bio-Imaging Research, Inc. (BIR) from Lincolnshire, Illinois.

The award-winning Waste Inspection Tomography for Non-Destructive Assay (WIT-NDA) system was developed by a team of engineers and physicists headed by Livermore's Patrick Roberson and Harry Martz. The system combines active and passive computed tomography and nuclear spectroscopy to accurately quantify all detectable gamma rays emitted from waste containers. The WIT-NDA is part of BIR's Waste Inspection Tomography system, which provides nondestructive examination and assay of radioactive waste and has been commercially available since August 1999. "The WIT-NDA is an excellent example of successful technology transfer between a DOE national laboratory and a small private business," says Richard Bernardi, WIT program manager for BIR.

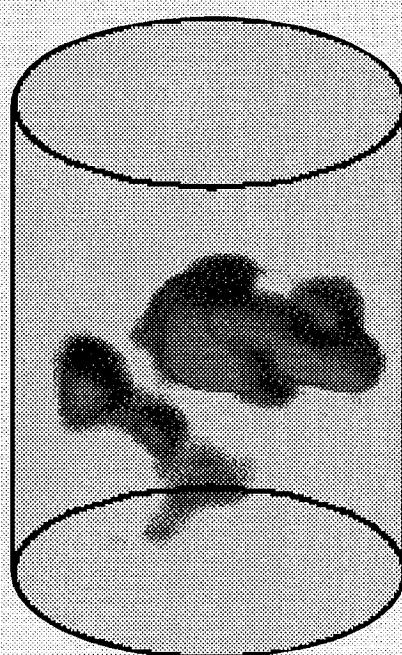
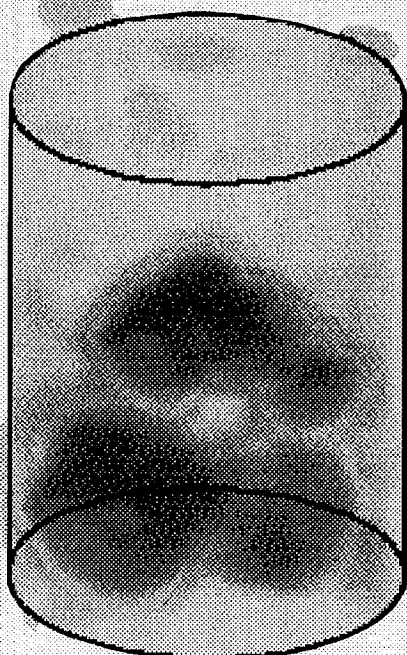
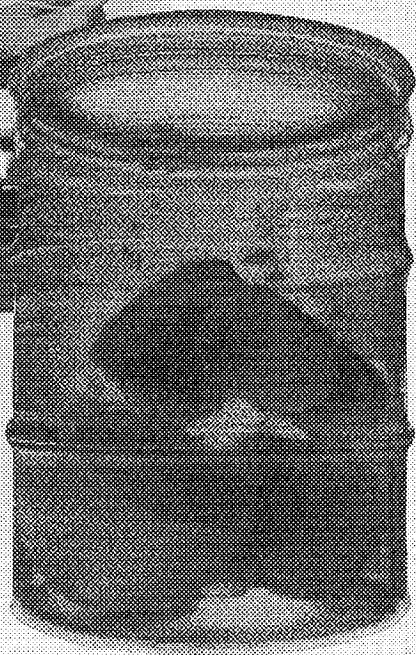
Safe and Accurate

As recently as 10 years ago, researchers could accurately assay the contents of a waste drum only by sampling, and for that they had to break the container seals. Opening containers meant workers—and possibly the public—risked exposure

to radiation and other hazardous materials. Beginning in 1990, engineer Harry Martz and physicist David Camp—both Livermore staff—headed a team to research ways to estimate the radioactivity of drum contents from the outside. Over the years, the team received funding for research and development from Livermore's Engineering directorate, the Laboratory Directed Research and Development program, and the Department of Energy's Environmental Management program, as well as from BIR.

The Livermore team developed a process that pinpoints where radioactive materials rest inside the drum and accurately quantifies and identifies these isotopes, whether they are plutonium, uranium, or some other gamma-ray-emitting radioactive waste. "This system is unique in that to use it, we don't need to open the container, we don't need any prior knowledge of the radioactive waste inside, and we don't have to calibrate the system to a specific waste stream," explains Roberson.

Determining the exact amount of radioactivity in each drum is essential to DOE's waste disposal efforts, Roberson notes. "DOE needs to characterize its radioactive wastes to verify that the waste drums meet criticality constraints and to differentiate transuranic from low-level



Data from an assay of a container of transuranic waste are rendered into views of (a) a typical transmission tomograph at high spatial and energy resolution, (b) the active data set, and (c) the passive data set, which gives the distribution of plutonium-239 in the drum. When the measurements are combined, radioisotopes can be identified, located, accurately measured, categorized, and certified for disposition.

wastes." Transuranic waste drums contain isotopes with atomic numbers greater than 92 (such as plutonium and uranium), radioactive decay half-lives greater than 20 years, and radioactivity levels greater than 100 nanocuries per gram of net waste weight.

Each class of waste is sent to a different disposal site. For example, the DOE Waste Isolation Pilot Plant (WIPP) in New Mexico accepts only transuranic wastes and, furthermore, has a limit on the total amount of radioactivity that can be placed within its underground repository. So waste drums must be nondestructively assayed to determine if they contain transuranic waste, and all radioisotopes in each drum must be inventoried to ensure that the WIPP limit is not exceeded. With NDA systems of lesser accuracy, waste regulators must err on the side of safety and designate waste disposal based on higher-end estimates of radioactivity.

Two-Step Process

The WIT-NDA is a unique two-step process that provides an assay of greater accuracy than previously possible. It collects two tomographic measurements—one active and one passive—using six external radioactive sources collimated to shine through the waste drum into six opposing, high-purity germanium detectors.

The first step is active computed tomography, which, like radiographic techniques that produce medical x rays, measure the attenuation of radiation intensity that travels from an external source through an object to a detector. In this active measurement, the external radiation sources are aimed at the sealed drum. The sources emit gamma rays at discrete energy levels. As the rays pass through the drum and the various densities of material within, they are attenuated to varying degrees. On the other side of the drum, the gamma-ray spectrometer measures the resulting, attenuated gamma radiation. Measurements are taken for 2.25-cubic-inch volumes over the entire drum (a total of 2,304 volume elements for a standard 55-gallon drum). By detecting and measuring the attenuated gamma-ray intensity

levels at specific energies, one can determine a map of the linear attenuation coefficient (a function of material density and atomic number) of the waste drum and its contents. These maps can be reconstructed to depict a drum's waste matrix attenuation per volume element and energy.

In the second step, called the passive measurement, the six transmission sources are shuttered. The six detectors then measure the gamma-ray spectra emitted from inside the drum. Measurements are taken over all the volume elements. During the passive computed tomography reconstruction, these intensities are corrected for attenuation caused by material between the isotope and the detector using the active attenuation map to provide an accurate measurement of radioactivity in the drum. The spectra are also used to automatically identify the isotopes within the drum, as each isotope emits a unique signature within the energy spectrum.

Unparalleled Accuracy

Other systems and techniques do not approach the accuracy of the WIT-NDA system. This was



The WIT-NDA team (from left): DeLynn Clark, David Camp, Dennis Goodman, Harry Martz, Jr., Jessie Jackson, Dan Decman, Pat Roberson, Erik Johansson, Steve Azevedo, and BIR members (inset) Dave Nisius, Dick Bernardi, and Dave Entwistle.

demonstrated by a DOE test that compared the performance of the WIT-NDA and fifteen other NDA systems. It was a blind test using a drum containing a simulated sludge with low levels of transuranic waste, one of the most challenging things to assay but typical of the types of wastes and drums the DOE must assay and dispose of. Of all the systems, the WIT-NDA performed the best by detecting the radioactivity within the sludge drum to within one percent of the known value. The nearest competing system detected only about 80 percent of the known radioactivity.

In the combined series of required DOE-sponsored tests for all NDA techniques that are proposed for certifying waste for disposal at WIPP, the WIT-NDA had a mean accuracy of 97.6 percent, with a precision within 4.1 percent. As Steven Cooke of DOE's Federal Energy Technology Center notes, "These results are truly exceptional in a difficult arena where par for the course is often plus or minus 50-percent accuracy."

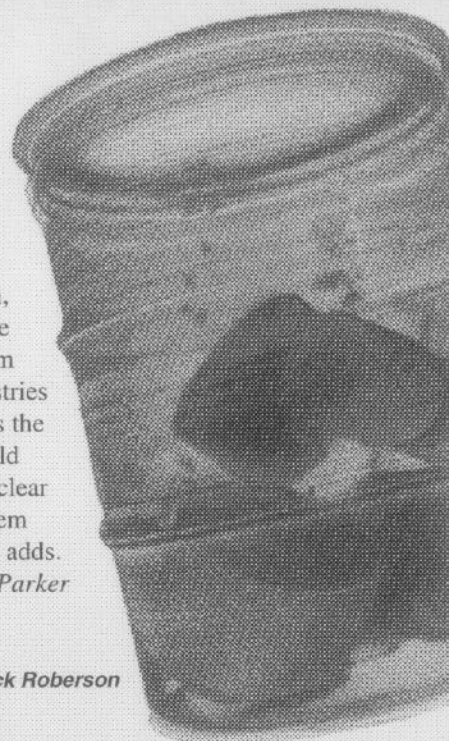
Other Applications

Roberson notes that since the WIT-NDA operates independently of whatever wastes are in the drum, it could also be used to measure the radioactivity in waste products from nuclear power plants or from industries that use radioactive tracers, such as the medical industry. "The system could also be used to quantify special nuclear materials in efforts to safeguard them and prevent their proliferation," he adds.

—Ann Parker

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Key Words: active and passive computed tomography, nondestructive evaluation, nondestructive assay (NDA), waste disposal, Waste Isolation Pilot Plant (WIPP), waste inspection tomography, R&D 100 Awards.



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